

Investigations of triggering mechanism of substorm through the analysis of Themis probe data

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In our previous paper, we have presented the result of our superposed epoch analysis applied to the Themis data in which the velocity moments were derived from the ESA, the low energy particle instrument with the upper limit energy of 25 keV. There are some concerns that the flow velocity of plasma obtained only with ESA can be underestimated since the ion fluxes above 25 keV energy range in the near Earth plasma sheet cannot be ignored. Thus we reexamined the Themis data taking into account the contribution of high-energy particles measured by high-energy particle instrument SST. As we expect, the flow velocity of plasma was found to be greater than that evaluated previously in the plasma sheet region of $X > -13$ Re. In our previous study, we pointed out that the earthward flows become quiet about 3 min prior to the auroral breakup, followed by abrupt enhancement of the earthward flows in the region of $-10 > X(\text{Re}) > -18$ at the time of auroral breakup (i.e., at $t=0$). Further, we proposed a new model for substorm onset called Catapult Current Sheet Relaxation Model. In a revised superposed epoch analysis result, we found that the relaxation starts first at $X \sim -12$ Re which corresponds to the inner edge of that current sheet and then propagates both earthward and tailward. The tailward propagation of the occurrence of earthward flows corresponds to the relaxation of the catapult current sheet. It is confirmed that about 1 min after the enhancement of the earthward flow at $X \sim -12$ Re, the catastrophic change of the current sheet reaches the tailward edge of the current sheet at $X \sim -18$ Re at which the magnetic neutral line is formed and the magnetic reconnection starts. Therefore we conclude that the flows appear about 1 min before the substorm onset and continue for about 2 min are produced by the relaxation of the catapult current sheet. In contrast, those follow the initial flows must be produced by the magnetic reconnection.

Keywords: substorm, Themis probes, current relaxation, magnetic reconnection

Global MHD simulation of substorm with effective resistivity models

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Magnetic reconnection is considered to play an important role in space phenomena such as substorm in the Earth's magnetosphere. In the MHD framework, the dissipation model is introduced for modeling of the kinetic effects. Tanaka and Fujita found that the normalized reconnection viscosity, one of the dissipation model employed there, gave a large effect for the dipolarization, central phenomenon in the substorm development process, though that viscosity was assumed to be a constant parameter.

It is well known that magnetic reconnection is controlled by microscopic kinetic mechanism. Horiuchi and his collaborators showed that reconnection electric field generated by microscopic physics evolves inside ion meandering scale so as to balance the flux inflow rate at the inflow boundary, which is controlled by macroscopic physics. That is, effective resistivity generated through this process can be expressed by balance equation between micro and macro physics. We also propose other resistivity model generated in wave-particle interaction, which was evaluated by Moritaka and Horiuchi.

In this paper, we perform substorm simulation by using the global MHD code developed by Tanaka with these effective resistivity models instead of the empirical resistivity model. We obtain the AE indices from simulation data, in which substorm onset can be seen clearly, and investigate the relationship between the substorm development and the effective resistivity model.

Keywords: substorm, global structure, magnetic reconnection, anomalous resistivity

Magnetic field fluctuations in the near-Earth magnetotail at substorm dipolarization onsets

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Using Geotail and THEMIS data, we have investigated low-frequency magnetic field fluctuations that were observed in the near-Earth magnetotail at $X \sim -10$ Re at substorm dipolarization onsets. A previous study showed that ballooning mode waves with a low-frequency range of ~ 0.01 Hz were observed near the magnetic equator just before dipolarization onsets for high plasma beta, while they were not observed for relatively low plasma beta. In the present study we analyze low-frequency waves in more detail and discuss the relationship between the ballooning instability, dipolarization, and substorm expansion onset.

Keywords: substorm, magnetotail, dipolarization, magnetic field fluctuation, ballooning

A shock wave in the magnetosheath observed in the substorm growth phase

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We detected a shock wave in the lower-latitude side to the cusp region in the magnetosheath during the substorm growth phase in the global MHD simulation. This shock is transient because it appears after the southward turn of the IMF and disappears after the onset of substorm. From analysis of the numerical data, we identify the shock as the fast shock. Therefore, this shock is caused by collision between the fast plasma flow in the magnetosheath and the high-pressure region of the cusp extended into the magnetosheath.

The points to be settled are acceleration mechanism of the magnetosheath plasmas and disappearance mechanism of this shock. As for the acceleration, the laval nozzle model [Yamauchi and Lundin, 1997] is one of the candidates, but the simulation result does not seem to support it. Otherwise, the magnetosheath plasmas are accelerated through release of the magnetic tension caused by magnetic field merging between the solar wind field and the magnetospheric field. As for the disappearance, it seems to coincide with the substorm onset. We find that the plasma pressure in the upstream side of the magnetosheath shock increases at the substorm onset. By analyzing the numerical results carefully, it is obtained that gradual increase in pressure triggered by sudden increase in pressure in the inner magnetosphere in the nightside propagates toward the dayside cusp region. This indicates that the magnetosheath plasma pressure will increase. Then, increase in the sound speed makes the supersonic flow the subsonic flow. Therefore, the shock wave disappears. It is noted that magnetic field erosion from the dayside magnetosphere to the lobe in the magnetotail is also seemed to be ceased at the same time. However, the erosion is active in the early phase of the growth phase and gradually less active in the latter phase of the growth phase. This result probably indicates that activity of the erosion does not control the formation of the shock.

Yamauchi, M. and R. Lundin (1997), The Wave-Assisted Cusp Model: Comparison to Low-Latitude Observations, *Phys. Chem. Earth*, 22, 729-734.

Keywords: shock wave, magnetosheath, cusp, MHD simulation, substorm

Rebound of BBF and vortical plasma motion in the near-Earth plasma sheet

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Magnetic reconnection in the near-Earth plasma sheet plays an important part in the geo-magnetospheric substorm. Then it is important to understand the plasma phenomena in this region associated with magnetic reconnection. Recent multi-satellite observations revealed that the interaction of a BBF in the plasma sheet with dipolar field lines of the Earth's magnetic field would result in formation of plasma vortices. In this study, we revealed the requirements, the region and the process of the development of the vortex using three dimensional MHD simulations on the basis of spontaneous fast magnetic reconnection model.

Keywords: MHD simulation, magnetic reconnection, near-Earth plasma sheet, vortical plasma motion, bursty bulk flow

A simulation study of the tail current sheet at the time of substorm onset

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A substorm is known as a primarily process to release stored energy in the Earth's magnetotail, and the magnetic reconnection as well as the tearing instability are thought to be related to the substorm. Although a number of models for substorm onset have been suggested so far, no consensus is not obtained yet. Recently we proposed a new scheme of substorm onset called "Catapult Current Sheet Relaxation Model" to comprehensively explain our result of the analysis of Geotail data. However, details of the model still remain to be solved. Thus, we conduct a study on a stability of the current sheet with highly stretched dipole magnetic field in order to clarify the mechanism of substorm onset and further to contribute to the progress of the space weather research.

Initially, we give a solution which is modified from the Harris solution that is widely used in the simulation of the magnetic reconnection, to include the contribution of Earth's dipole magnetic field. Then, we run 2-1/2D full-particle PIC simulation code for the approximated Earth's magnetotail. In this simulation, initial locations of particles are determined with a quiet start method to suppress the numerical noise with limited number of particles. We then investigate the relation between the distribution of northward magnetic field originated from the Earth's dipole magnetic field and the location of the magnetic neutral line, as well as the development of the tearing instability and its relationship to the occurrence of the magnetic reconnection.

Keywords: Substorm, Magnetic reconnection, Tearing instability, PIC simulation

Tailward plasma flow observed in the near-Earth magnetosphere

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Magnetic reconnection in the near-Earth magnetotail produces earthward fast plasma flow called Bursty Bulk Flow (BBF) and tailward plasma flow. On the other hand, interaction of this BBF with dipolar field lines of the Earth's magnetic field results in tailward rebound of a BBF. In this study, the differences between these two tailward plasma flows are investigated using GEOTAIL observations and computer simulations. Virtual satellite observations in the three dimensional MHD simulations on the basis of spontaneous fast reconnection model are compared with results of the superposed epoch analyses of GEOTAIL observation data.

Keywords: reconnection, tailward

Streamline reconstruction of the front part of magnetotail reconnection jets

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We present an in-depth analysis of multiple plasma jet fronts observed on 15 August 2001 by the Cluster spacecraft (at geocentric distance of about 19 Re) in a post-midnight current sheet of Earth's magnetotail, first reported by Hwang et al. (2011). Such jet fronts, accompanied by an increase in the northward magnetic field component (B_z), are suggested to be a key ingredient for earthward injection of plasma and magnetic flux. In part of fast earthward jets where the field is directed earthward ($B_x > 0$), ion velocity distributions consist of two populations, Alfvénic field-aligned beam and cooler ions convected toward the sheet center, supporting that the jets resulted from magnetic reconnection tailward of Cluster. Four-spacecraft timing method and deHoffmann-Teller analysis both show that the entire structure traveled earthward and dawnward. Based on reconstruction of streamlines using a Grad-Shafranov-like equation for flow transverse to a unidirectional field (Hasegawa et al., 2007), it is suggested that a vortex with a diameter of several Re existed near the dawnside edge of each jet front. The results are suggestive of an MHD-scale interchange type instability developed at the front of a two-dimensional (broad) reconnection jet (e.g., Nakamura et al., 2002), although the possibility of multiple bursts of transient and three-dimensional (localized) reconnection cannot be ruled out.

References:

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Hwang, K.-J., M. L. Goldstein, E. Lee, and J. S. Pickett (2011), Cluster observations of multiple dipolarization fronts, *J. Geophys. Res.*, 116, A00I32, doi:10.1029/2010JA015742.

Nakamura, M. S., H. Matsumoto, and M. Fujimoto (2002), Interchange instability at the leading part of reconnection jets, *Geophys. Res. Lett.*, 29(8), 1247, doi:10.1029/2001GL013780.

Keywords: magnetotail, magnetic reconnection, interchange-type instability, Grad-Shafranov equation, jet front

Evolution of Field Structure and Energy in a Solar Flare

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Solar activity, such as solar flare, closely relate to geo-magnetosphere. Therefore, the prediction of solar flare is important to the forecast of the space weather. Then, at first, we have to understand the evolution of field structure before and after the solar flare.

Solar Optical Telescope (SOT) on the Hinode satellite has provided us the high resolution magnetic field vector data on the photosphere. In this study, we extrapolate the three dimensional coronal magnetic field from these observed data using magnetofrictional method, and investigate the evolution of field structure and free energy before and after the solar flare.

Keywords: Reconnection

Comparison between emission intensities of magnetic conjugate aurora

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Aurora has a lot of information on the magnetosphere along a magnetic field line. The magnetic field of the Earth has a shape close to a dipole, and two ground points connected by a magnetic field line like a Husafell and Syowa Station pair are called geomagnetic conjugate points. The aurora which appears over both points is called geomagnetic conjugate aurora. We observed aurora simultaneously at magnetic conjugate points and compared intensity, shape, and appearance frequency of the conjugate auroras. In general, the conjugate aurora becomes similar shape, if the magnetosphere is symmetric. However, the conjugate property of the aurora along with the states of the magnetosphere and the ionosphere is not always maintained. When, the magnetic field line dynamically change in response to temporal variations in the interplanetary magnetic field (IMF) orientation, it has been sometimes observed that similar auroras change suddenly into dissimilar auroras in a few minutes. One of the causes of this non-conjugate property is an asymmetric diversity in the northern and southern field-aligned acceleration regions that exist around altitudes of 3000~10000 km. Difference in the auroral intensity could result from the interhemispheric difference in the fluxes of auroral particle precipitation. In this study we compare auroral intensities during an event on September 9 and 10, 2011, and also statistically compare emission intensities of auroras observed at Syowa Station and Iceland conjugate points.

Keywords: magnetic conjugate aurora

Development of the automatic observation system for VLF/ELF waves at subauroral latitudes

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One of the mechanisms of pulsating aurora is that VLF/ELF waves generated around magnetic equator modulate particle precipitation through wave-particle interaction. In this model, correlations between pulsating auroras and VLF/ELF waves observed at ground are expected. Indeed, examples of such good correlations were reported before (Tsuruda et al., 1981).

In those days, however, all data were in analog recordings. It was difficult to analyze the frequency characteristics and wave forms in detail. Thus, we made a campaign observation of high-time resolution measurements of auroras and VLF/ELF waves at Athabasca (54.72N, 246.69E, MLAT=61.3) and Fort Vermillion (58.38N, 243.99E, MLAT=64.5), using two loop antennas and several auroral cameras for February 16-26, 2012.

The amount of VLF/ELF wave data obtained from this campaign is enormous, because the sampling rate of the wave data is 100kHz. The purpose of this study is to develop automatic software to visualize the wave characteristics. We put instrument name, date, time, sampling frequency, number of channels and site name into the name of data files. We visualize the data as high-resolution dynamic spectra to find interesting events. These procedures are automated using Linux shell commands. In this presentation we will show these procedures and preliminary results obtained from this campaign at subauroral latitudes.

Keywords: subauroral latitudes, pulsating aurora, VLF wave, ELF wave, automatic observation system, high-time resolution

Data analysis of ELF emissions in the vicinity of magnetic equator observed by AKEBONO

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Electromagnetic ion cyclotron wave and magnetosonic wave were frequently observed around the magnetic equator by AKEBONO [1,2]. On the other hand, the next inner magnetosphere explorer mission named "ERG" is now under planning [3]. The ERG mission aims to investigate the plasma dynamics of the inner magnetosphere by measuring three-dimensional plasma distributions over a broad energy range from eV to MeV and electric and magnetic field from DC up to HF range simultaneously near the equatorial plane. It is pointed out that ion cyclotron wave and magnetosonic wave play important roles in wave-particle interaction in the radiation belt.

In the present study, therefore, we analyze these data again observed by Akebono to examine their characteristics such as polarization and spectrum feature. According to the analyses, we also propose required frequency and time resolution and additional functions to be implemented on the Plasma Wave Experiment (PWE) onboard ERG to achieve detailed measurements of these ELF emissions.

[1] Y. Kasahara, A. Sawada, M. Yamamoto, I. Kimura, S. Kokubun, and K. Hayashi, Ion Cyclotron Emissions Observed by the Satellite Akebono in the vicinity of the Magnetic Equator, *Radio Science*, 27, 347-362, 1992.

[2] Y. Kasahara, H. Kenmochi, and I. Kimura, Propagation Characteristics of the ELF Emissions Observed by the Satellite Akebono in the Magnetic Equatorial Region, *Radio Science*, 29, 751-767, 1994.

[3] ERG Working Group, ERG (Energization and Radiation in Geospace) working group proposal, 2008.

Keywords: electromagnetic ion cyclotron wave, magnetosonic wave, radiation belt, AKEBONO, ERG

Evaluation of high-energy electron Detector for Probing the Inner Magnetosphere in High-counting Conditions

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There are regions where has particles over a broad energy range, from a few electron volts to more than 10MeV in the earth's magnetosphere. Also in radiation belt of inner magnetosphere, high energy electron were observed increased at recovery phase of magneticstorm. Magnetosphere is considered as infrastructure is use now more. And to understand the variation is important for social and science. There is project that integrated observation by ERG satellite. This research is Capability Evaluation of high energy detector (HEP-e) that is used into ERG satellite. At electron flux increase to , counting is occur saturation by dead time of IC chip for read of HEP-e. Reduce sensitive area of detector, and cover high counting by incident particle decrease.

This research used Cs137 and few radiation source that emit lower energy. As Result detector occurred counting loss of Cs137 emitted electron when increased incident particle. But counting loss was decreased by reduce sensitive area. Also spectrum occur be shift high energy side in high counting condition. This weigh continue experiment with result simulation of Geant4 that is simulation soft.

Keywords: Inner Magnetiosphere, Electron Detector, Magnetic storm

Latitude dependence of Pi2 Pulsation frequency observed by the mid-latitude SuperDARN radars and the THEMIS satellites

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At mid-latitudes, Pi2 pulsations appear clearly on the nightside at substorm onsets. Several studies suggested that a transient Alfvén waves might contribute to the excitation of Pi2 pulsations at high latitudes on the nightside. On the other hand, fast mode waves trapped between the ionosphere and plasmasphere are responsible for Pi2 pulsations at mid and low latitudes on the nightside. Using the Sweden And Britain auroral Radar Experiment (SABRE) coherent radar at auroral and sub-auroral latitudes, Yeoman et al. [1991] found that the radar could distinguish between these two types of Pi2 pulsations and suggested that the mid latitude is transition region of these two types of Pi2 pulsations. Few studies have been examined the characteristics of Pi2 pulsations over wide geomagnetic latitude, using radars located at mid latitude.

We report on one event of Pi2 pulsation at 09:10 UT on 11 August 2010 detected simultaneously by the Hokkaido, Tiger, and Unwin SuperDARN radars and THEMIS-A, -D, -E satellites when they were located in the pre-midnight sector. THEMIS satellites observed Pi2 pulsations predominantly in the compressional and radial components of the magnetic field and the azimuthal component of the electric field when satellites were located at $L < 4$ inside the plasmasphere. These pulsations had a predominant frequency at 14 mHz and high coherence (~ 1) with the H-component Pi2 pulsations at Kakioka (KAK: magnetic latitude 27.47; magnetic longitude 209.2 degrees). The four radars detected Pi2 pulsations as fluctuation in the Doppler velocities while operating with themiscan mode, which provides 8-s sampling data. Pi2 pulsations in Doppler velocities of echoes backscattered at lower latitude had predominant frequency at 14 mHz while Pi2 pulsations observed at higher latitude by the radars had predominant frequency of both 14 mHz and 21 mHz. These results may indicate that the radars detected harmonic structures of Pi2 pulsations in the plasmasphere.

Estimation of magnetic flux diffusion region using a system of Magnetic Field Tracing in Global MHD simulations

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We developed a system of Magnetic Field Tracing in Global MHD simulations in order to understand magnetosphere convection. To trace magnetic flux tube, 'Frozen-in' needs to hold. We investigated the time revolution of magnetic flux and visualize magnetic diffusion regions. As a result, we find that magnetic diffusion regions change depending on IMF directions. In this lecture, we discuss the application of the magnetic field tracing system to space weather.

Keywords: magnetic field line, frozen-in, magnetosphere convection, space weather

Particle simulations about LH plasma waves observed by Geotail spacecraft

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According to our previous study, LH plasma waves are observed in Lobe and PSBL region in the magnetosphere. We studied several plasma parameters at the time when LH waves were observed, and found that LH waves were observed with the large perpendicular velocity of ion and the earthward ion flow. In addition, the LH plasma waves observed with the earthward ion flow have low frequencies, and the strengths of those LH plasma waves are relatively large. These results suggest that strong LH plasma waves are observed in the boundary region where ion flow usually exist, such as Lobe region close to PSBL. In addition, LH plasma waves are observed when ion velocity perpendicular to the ambient magnetic field is enhanced and earthward ion flows are observed.

On the basis of these results, we are going to perform 2-dimensional particle simulations about LH plasma waves observed by EFD. In these simulations, we examine effects of perpendicular on thermal velocity and parallel ion drift velocity on the generation mechanism of LH plasma waves. We will farther investigate the occurrence conditions of LH plasma waves to clarify the generation mechanism of these waves and their effects on local plasma environment in the magnetosphere.

Keywords: Lower Hybrid plasma wave, magnetosphere, statistical analysis, ion flow, wave-particle interaction

Global magnetic flux circulation in the magnetosphere during obliquely northward interplanetary magnetic field periods

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The structure of the magnetosphere during northward interplanetary magnetic field (IMF) periods is less well known than is generally thought. For example, few people recognize that because open field lines drape over the dayside magnetosphere (the so-called overdraped lobe), the low-latitude boundary layer is located on open field lines. Also, as for the steady-state magnetic flux circulation resulting from reconnection, only the circulation mode that is completed within the lobe [Russell, 1972] has been considered in the past. Consequently, the convection cell that appears in the ionosphere has been interpreted as the so-called lobe cell for all cases. However, Watanabe and Sofko [2009] has pointed out that considering the magnetic topology, the lobe circulation view is not necessarily true, and in fact another mode of magnetic flux circulation is dominant during northward IMF periods. In that new idea, IMF-lobe reconnection and lobe-closed reconnection occur sequentially in both hemispheres to maintain steady-state flux circulation by reciprocating magnetic flux between the two reconnection processes. This new idea has not been accepted widely, however. One reason is the difficulty in visualizing the three-dimensional topology of the magnetic field, with the result that the discussion stops at the most rudimentary level. The authors previously showed that the outcome of numerical magnetohydrodynamic simulation was consistent with the aforementioned circulation mode. When the IMF clock angle points about 20 degrees from due north, the convection patterns in the ionosphere exhibit those expected from the theoretical prediction. In the current study, we further advance the analysis of the simulation results, and confirm that the magnetic flux circulation mode is in fact that predicted. In addition, we visualize the circulation mode using computer graphics techniques so that everyone can understand the reconnection processes involved. For this purpose, we first determine and visualize magnetic nulls, separatrices, and separators, which are essential in understanding the three-dimensional structure of the magnetosphere. We next show the existence of a streamline that crosses separatrices sequentially in the following order: IMF-lobe-closed-lobe-IMF. This proves the above-mentioned magnetic flux circulation mode. In the presentation, we will also refer to observations that are relevant to the circulation mode.

References

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Keywords: magnetic topology, magnetic reconnection, magnetic null, separatrix, separator